IS 7504 (1995): Gears - Cylindrical Gears - Accuracies - Methods of inspection [PGD 31: Bolts, Nuts and Fasteners Accessories]

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(Reaffirmed 2005)

भारतीय मानक

गियर — बेलनाकार गियर — परिशुद्धताएं — निरीक्षण की पद्धतियाँ

(पहला पुनरीक्षण)

Indian Standard

GEARS — CYLINDRICAL GEARS — ACCURACIES — METHODS OF INSPECTION

(First Revision)

UDC 621·833·1 : 620·111·1

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Price Group 9

Gears Sectional Committee, LM 13

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Gears Sectional Committee had been approved by the Light Mechanical Engineering Division Council.

This standard was originally published in 1974. The present revision incorporates the latest internationally accepted techniques for inspection of cylindrical gears which includes inspection of gear blanks of meshing gears, inspection of teeth forms of gears pairs and the inspection of gear pairs in assembled conditions. The gears are classified into 12 grades based on their accuracies. The revision also incorporates the methods for determining individual errors, schematic for electronic pitch testing equipment, schematic circuit for single flank testing and measurement of double flank total composite error

Assistance has been derived from the following standards while revising the standard:

i) DIN 3960 : 1987 'Definitions parameters and equations for involute cylindrical gears and gear pairs', issued by DIN. Deutsches Institut für Normung, Germany.

ii) DIN 3961 : 1978 'Tolerances for cylindrical gear teeth', issued by DIN. Deutsches Institut für Normung, Germany.

iii) DIN 3967 : 1978 'System of gear fits, backlash tooth thickness allowances, tooth thickness tolerances, principles', issued by DIN. Deutsches Institut für Normung, Germany.

IS 3681 : 1994 'Gears -- Cylindrical gears — Accuracies (*first revision*)' may be referred for definitions and notations.

In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

GEARS — CYLINDRICAL GEARS — ACCURACIES METHODS OF INSPECTION

(First Revision)

1 SCOPE

1.1 This standard covers the general plan for cylindrical gears of involute, modified involute flank forms, comprising of gears with straight or inclined teeth for connecting parallel shafts.

1.2 This standard covers the inspection methods for gear teeth on cylindrical gears of module 1 to 70 and with reference circle diameter up to 10 000 mm graded in 12 gear tooth qualities.

2 REFERENCES

IS 3681 : 1994 'Gears — Cylindrical gears — Accuracies (*first revision*)' may be referred for definitions and notations.

3 SYMBOLS

a''	–	Radial pitch distance (double flank pitch distance)
b	–	Face width
d	–	Reference circle diameter
d_a	–	Top diameter, Blank diameter
d_b	–	Base circle diameter
d_M	–	Measuring circle diameter
f_f	–	Profile form error
f_i'	–	Single flank tooth to tooth composite error
f_i''	–	Double flank tooth to tooth composite error
f_p	–	Individual pitch error
f_{pe}	–	Base pitch error
f_u	–	Tooth to tooth pitch error
$f_{H\alpha}$	–	Profile angle error
$f_{H\beta}$	–	Flank line angle error
$f_{\beta f}$	–	Longitudinal form error
$\bar{h}$	–	Chordal height
$\bar{h}_c$	–	Constant chordal height
j_n	–	Normal backlash
k	–	Number of teeth measured
m	–	Module
m_n	–	Normal plane module
m_t	–	Transverse module
P_b	–	Base pitch
s	–	Tooth thickness
s_{Max}	–	Maximum tooth thickness
s_{Min}	–	Minimum tooth thickness
s_b	–	Tooth thickness on base cylinder
$\bar{s}_n$	–	Chordal tooth thickness
$\bar{s}_c$	–	Constant chordal tooth thickness
x	–	Addendum modification co-efficient
z	–	Number of teeth
z_v	–	Virtual number of teeth
A	–	Factor (Table 7)
C_1	–	Factor (Table 8)
C_2	–	Factor (Table 9)
D_M	–	Measuring pin or ball diameter
F_f	–	Total profile error
F_i'	–	Single flank total composite error
F_i''	–	Double flank total composite error
F_p	–	Total cumulative pitch error
F_{pk}	–	Cumulative pitch error over k pitches.
$F_{pz/8}$	–	Cumulative pitch error over 1/8 of periphery
F_β	–	Total alignment error
F_r	–	Radial run-out error
IT	–	Tolerance grade
M	–	Tooth width
M_1	–	Tooth width for module 1
M_R	–	Dimension over pins or balls
R_P	–	Range of pitch errors
R_s	–	Tooth thickness fluctuation
α	–	Pressure angle
α_n	–	Normal pressure angle
α_t	–	Transverse pressure angle
α_w	–	Working pressure angle
α_{wt}	–	Transverse working pressure angle
α_R	–	Pressure angle, pin or ball
α_{Rt}	–	Transverse pressure angle, pin or ball
β	–	Helix angle
β_b	–	Base helix angle
ψ	–	Tooth thickness semi-angle

4 INSPECTION METHODS FOR CYLINDRICAL GEARS

4.1 The logical order of manufacture of a gear pair is:

a) Machining the blanks of the two gears,
b) Cutting of the teeth of the two gears, and
c) Assembling the toothed wheels in operating condition.

It is, therefore, normal to carryout the successive inspection in corresponding order:

1. Inspection of the blanks of the two gears.
2. Inspection of the teeth of the two gears, and
3. Inspection of the assembly conditions of the two gears.

5 INSPECTION OF THE GEAR BLANKS

5.1 Reference Axis

In the case of pinions or wheels with bores, the axis of the bore is adopted as the reference axis.

In the case of pinions on shafts, the reference axis shall be the bearing axis of the bearings.

In order to facilitate the operations of machining, inspection and assembly of toothed wheels, it is recommended that radial and axial auxiliary reference surfaces should be indicated clearly on the working drawings (*see* Fig. 1).

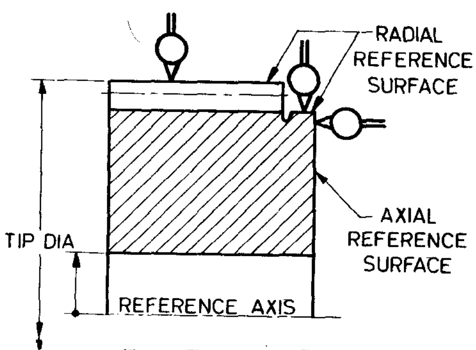


FIG. 1 REFERENCE SURFACES

5.2 Tip Cylinder

5.2.1 *Tip Diameter*

The value of the tip diameter is not of essential importance. In cases where the apparatus for inspecting the tooth thickness rests on the tip cylinder, allowance should be made for the tip diameter error.

5.2.2 *Radial Run-Out*

This is the total range of movement of an indicator stylus which is in contact with the tip cylinder during a complete revolution of the gear (*see* Fig. 1). This check is important only in the case where certain tooth inspection instruments rest on the cylinder.

5.3 Reference Surfaces

5.3.1 *Radial Run-Out*

This is the total range of movement of an indicator stylus which is in contact with the radial cylindrical reference surface during a complete revolution of the gear.

5.3.2 *Axial Run-Out (Wobble)*

This is the total range of movement of an indicator stylus which is in contact with the axial reference surface during a complete revolution of the gear.

5.4 Tolerances on Gear Blanks

The tolerances on gear blanks shall be as given in Table 1.

6 INSPECTION OF GEAR TEETH FOR INDIVIDUAL ERRORS

6.1 Circular Pitch Errors

Circular pitch errors called as pitch errors in short, are measured on the reference circle or any other circle as close to it as possible and concentric with respect to the gear axis. The difference between the measuring circle diameter d_M and the reference circle diameter d influences the measurement of the error by the factor d_M/d and these errors are generally negligible.

The measured values are also affected by eccentricity of the teeth with respect to reference axis and also by profile error.

Inspection of the pitch by measuring the deviation from the design value is normally performed only on high precision gears where exact angular transmission is indispensable. A tooth flank is butted against a fixed anvil in the region of the reference circle while a movable measuring feeler senses the corresponding flank of the adjacent tooth. The differences between the adjacent pitches can be read from a dial indicator (*see* Fig. 2).

Eccentricity of the teeth with reference to the gear axis gives rise to an error curve of overall sinusoidal form.

When pitch measurement is carried out using a hand operated comparator, the computation of the individual pitch error, tooth to tooth pitch and total cumulative pitch error is carried out as given in Table 2 and the graph of the errors can be drawn from the values thus computed.

The difference between the consecutive measured values gives tooth to tooth pitch error, f_u. Then the algebraic mean value is calculated from all the measured values. The difference between the measured values and the mean value gives individual ptich error, f_p. The algebraic addition of individual pitch error f_p gives the cumulative pitch error. The total cumulative pitch error F_p is given by the difference between maximum and minimum values of cumulative pitch error.

The circular pitch errors can also be measured by using electronic pitch testers. Individual pitch errors are

Table 1 Tolerances on Gear Blanks (µm)

(*Clause* 5.4)

Quality	1	2	3	4	5	6	7	8	9	10	11	12
Bore error of form	IT1	IT2	IT3	IT4	IT4	IT6	IT6	IT6	IT7	IT8	IT8	IT8
Shaft error of form	IT1	IT2	IT3	IT4	IT4	IT5	IT5	IT5	IT6	IT7	IT8	IT8
Tip diameter	IT6	IT6	IT7	IT7	IT7	IT7	IT7	IT8	IT8	IT9	IT11	IT11
1) Radial run-out of Tip cylinder Radial run-out of the reference surface Axial run-out of the reference surface	2.5		$0.01d_a + 5$			$0.016d_a + 10$			$0.25d_a + 15$	$0.04d_a + 25$		

NOTE — d_a – Blank diameter, mm.

1) When the tip cylinder is used as a datum surface for a checking instrument.

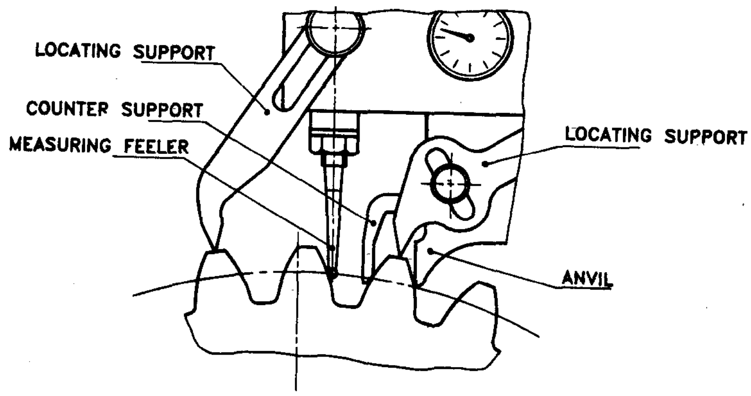


FIG. 2 INSPECTION OF GEAR TEETH FOR INDIVIDUAL ERRORS

measured with an attachment for involute and helix testers, which operates on the comparison pitch measuring principle and at the same time defines a mean value. Figure 3 shows a schematic of an electronic pitch testing equipment. The attachment compares the initial comparison pitch value '*O*' of any one pitch of the gear with all subsequent pitches. This is achieved with the electric tracer '*K*' which, with its pair of styli '*M*' switched to difference measurements, measures values in relation to the initial datum value '*O*'. When the last measured value has been recorded, electronic unit '*R*' automatically evaluates the mean value which is then drawn automatically as a straight line through the previously recorded pitch diagram. The actually recorded individual pitch errors are then read off along the line.

6.1.1 *Individual Pitch Error, f_p*

Individual pitch error, f_p is the difference between the actual value of a single transverse pitch and nominal transverse pitch.

In a gear with z teeth there are z individual pitch errors of the right flank and as many of the left flanks. The errors, f_p are obtained as the difference between the individual measured value and the mean of all z' measured values.

6.1.2 *Cumulative Pitch Error, F_{pk}*

This is the deviation of the actual dimension of a pitch interval over k individual pitches from the corresponding nominal value. The cumulative pitch error is obtained as the algebraic sum of the k individual pitch errors contained in the interval, provided the error of measurement is sufficiently small.

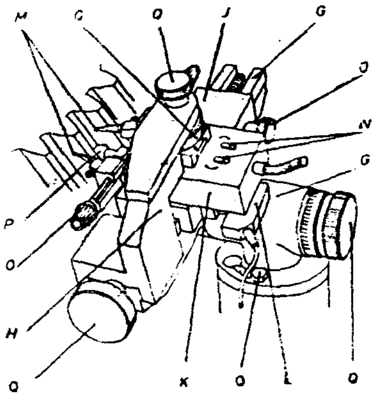
$$F_{pk} = \sum_{0}^{k} f_p$$

Table 2 Pitch Errors on Gears

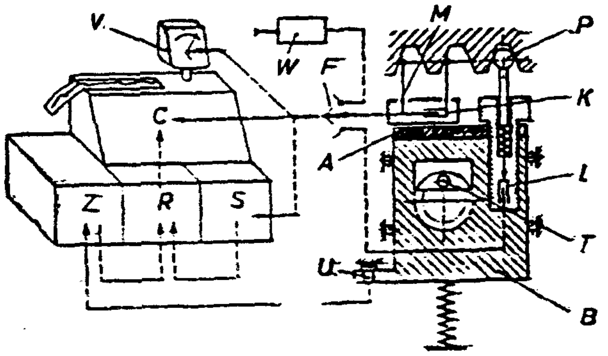
(Clause 6.1)

Pitch No.	Measured Value	Tooth to Tooth Pitch Error	Individual Pitch Error	Cumulative Pitch Error
	µm	f_u, µm	f_p, µm	F_p, µm
1	0	1	+1	+1
2	+3	3	+4	+5
3	+5	2	+6	+11
4	+1	4	+2	+13
5	–1	2	0	+13
6	–3	2	–2	+11
7	–5	2	–4	+7
8	–3	2	–2	+5
9	–6	3	–5	0
10	–3	3	–2	–2
11	–1	2	0	–2
12	+1	2	+2	0

NOTE — Mean value $\frac{+10-22}{12} = -1$ (Mean value to be rounded off to the nearest micrometer).



G Base or guide body for *H* and *J*
H Carrier side for electric tracer *K*
J Carrier side for electric tracer *L*
K Electric tracer for pitch tests, etc
L Electric tracer for true running tests
M Pair of tracer styli of *K* switched to different measurements.
N Selector switch for separate tracer pressure direction setting for *M*
O Fine setting screw for adjusting the distance between tracer styli of *M*
P Supporting ball pin or ball/type stylus of *L* for true running tests
Q Measuring head adjustment swivelling and locking members



Z Counting mechanism
R Computer for mean value evaluation
S Measured value store
T Stroke mechanism
U Stroke restriction
V Indicator instrument
W Electric tracer for involute tests, etc

FIG. 3 ELECTRONIC PITCH TESTING EQUIPMENT

If the errors of all the pitch intervals are measured from a particular reference tooth profile or calculated from the individual errors, f_p according to the above equation and then plotted against the corresponding teeth numbers, then the cumulative pitch errors are obtained as per Fig. 4.

6.1.3 *Cumulative Pitch Error Over 1/8 of Periphery,* $F_{pz/8}$

This is the cumulative pitch error over an interval of 1/8 circumference of the gear ($k = z/8$).

6.1.4 *Total Cumulative Pitch Error,* F_p

The maximum cumulative pitch error in a gear is called the total cumulative pitch error. It is indicated without sign and is obtained from the cumulative pitch errors as the difference between the algebraic maximum value and the algebraic minimum value.

6.1.5 *Range of Pitch Errors,* R_p

This is the difference between maximum and minimum actual values of the transverse pitches of the right or left flanks of a gear.

6.1.6 *Tooth to Tooth Pitch Error,* f_u

The tooth to tooth pitch error is the difference between the actual values of two successive right or left transverse pitches.

Tooth to tooth pitch errors are directly obtained from circular pitch measurements as the difference of measurements of neighbouring pitches.

6.1.7 *Base Pitch Error,* f_{pe}

Base pitch error is the difference between the actual and nominal values of the base pitch. Deviations measured in the transverse plane are denoted by f_{pet} and in the normal plane by f_{pen}.

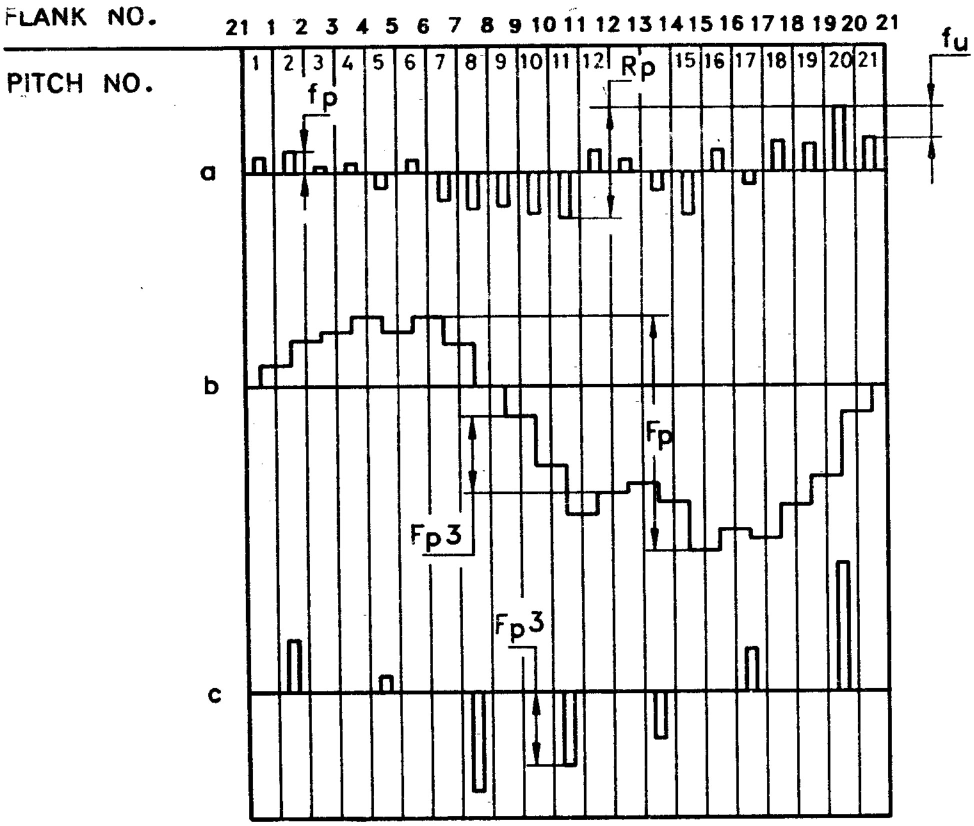
Inspection is performed by means of a base pitch measuring instrument which is pre-adjusted to setting gauges. Either portable or bench instruments can be employed. In both cases, measurement is independent of the gear axis with no influence of radial run-out on the base pitch. *See* Fig. 5.

The absolute value of the base pitch on the line of action is an idicative of the pressure angle. Error in the base pitch implies an error in the pressure angle.

For spur gears, error in the pressure angle can be determined by means of the equation:

$$p_b = \pi m \cos\alpha$$

For helical gears, the measured error of the base pitch may be due to an error in the pressure angle or in the helix angle or both. Measurement of the base pitch on the line of action is particularly important for the gears produced by single tooth cutters.



a — Individual pitch error, f_p marked as vertical blocks between the flnak numbers.
R_p – Range of pitch error, f_u – Tooth to tooth pitch error

b — Total cumulative pitch error referred to flank 21.
F_p – Total cumulative pitch error.

c — Cumulative pitch error over intervals of every three teeth, f_{p3} ($k = 3$) shown as vertical blocks in the middle of the flanks.

FIG. 4 DETERMINATION OF PITCH ERROR (Eg : 21)

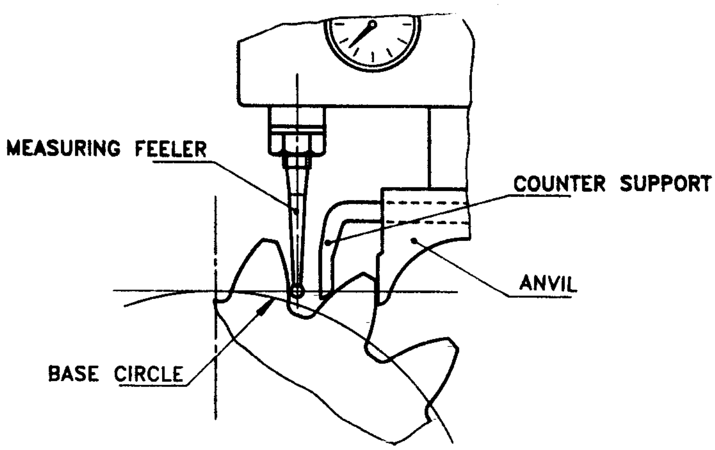


FIG. 5 MEASUREMENT OF BASE PITCH ERROR

6.2 Flank Deviations

6.2.1 *Inspection of the Involute Profile*

This inspection, together with the pitch measurement is of foremost importance in the schedule of individual error tests, since for the correct meshing and the measurement of gears it is essential that the tooth flanks are really involutes.

The form of the profile can be optically enlarged and compared with the drawing of an involute, especially in case of fine pitches. The difficulty lies in determining the position of the profile in relation to the base circle.

Usually the test is made by means of an apparatus which generates the true involute by rolling a straight edge on a base circle disc and records the deviations of the actual tooth profile to an enlarged scale on graph paper. *See* Fig. 6. The diameter of the base circle disc follows from the equations:

For spur gears:

$$d_b = z.m \cos\alpha$$

For helical gears:

$$d_b = z.m \frac{\cos\alpha}{\cos\beta_b}$$

By plotting the flank deviations with the help of a flank tester, flank test graph as shown in Fig. 7 can be obtained.

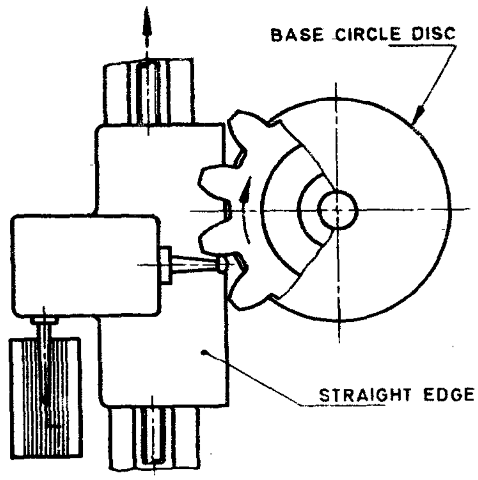
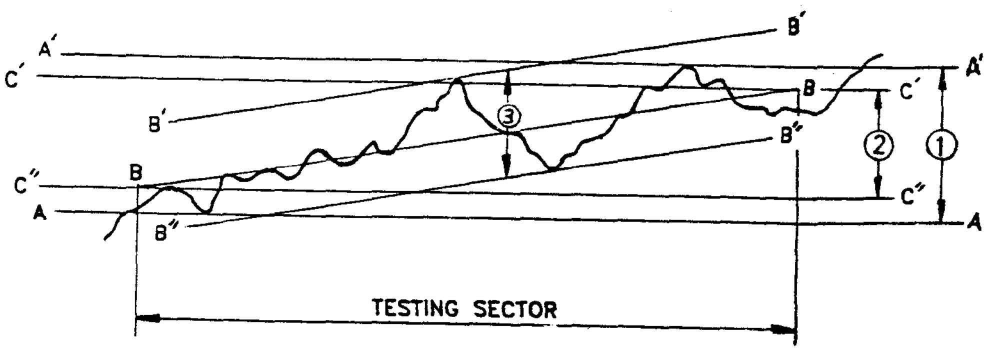


FIG. 6 INSPECTION OF TOOTH PROFILE



	Profile	*Flank Line*
1	Total profile error, F_f	Total alignment error, F_β
2	Profile angle error $f_{H\alpha}$	Flank line angle error $f_{H\beta}$
3	Profile form error, f_f	Longitudinal form error $f_{\beta f}$
BB	Intermediate actual profile	Intermediate actual flank line
AA, A'A'	Nominal profile	Nominal-flank lines which envelop the actual flank
B'B', B''B''	Actual profile	Actual helical lines which envelop the actual flank
C'C', C''C''	Nominal profile	Nominal flank lines which cut the actual flank lines at the beginning and end point of the test range

FIG. 7 FLANK DEVIATIONS AND TEST GRAPH

6.2.1.1 *Total profile error, F_f*

In a test graph, as shown in Fig. 7, the total profile error, F_f is the measurement made perpendicular to the paper feed direction between the parallel lines *AA* and *A'A'*, drawn in the direction of the paper feed within the profile test region through the extreme point of the test graph. The desired modifications from the involute form are taken into consideration by corresponding deviations of the lines *AA* and *A'A'* from the straight line.

6.2.1.2 *Profile form error, f_f*

In a test graph as shown in Fig. 7, the profile form error f_f is the measurement taken perpendicular to the paper feed direction between the lines *B'B'* and *B''B''* which are parallel to the actual involute *BB*. Line *BB* is drawn to average the involute curve which touches the test curve within the profile test region.

6.2.1.3 *Profile angle error, $f_{H\alpha}$*

In a test graph as shown in Fig. 7, the profile angle error, $f_{H\alpha}$, is the measurement taken perpendicular to the direction of paper feed between the lines *C'C'* and *C''C''* parallel to *AA*, which cut the line *BB* at the start and end point of the profile test region respectively.

6.2.2 *Inspection of Tooth Alignment Errors*

6.2.2.1 *Total alignment error, F_β*

For measuring the tooth alignment errors, Fig. 8 shows an apparatus that imparts the gear, a rotation corresponding to the helix angle set on the apparatus. This rotation, combined with the movement of the feeler parallel to the gear axis, results in a vertical straight line diagram, if the acutal helix angle coincides with the design value.

In a test graph as per Fig. 7, the total alignment error F_β is the distance, measured perpendicular to the paper feed direction, between the parallel lines *AA* and *A'A'* which are drawn in the direction of paper feed within the flank line test region through the extreme points of the test graph. The intended deviations from the helix line form are taken into account by corresponding deviations of the lines *AA* and *A'A'* from the straight line.

6.2.2.2 *Longitudinal form error, $f_{\beta f}$*

The longitudinal form error, $f_{\beta f}$ of a tooth flank is the distance between the two helix lines with the actual lead, which touch and envelop the actual flank line within the flank line test region taking into account the intended deviations from the helix line form.

6.2.2.3 *Flank line angle error, $f_{H\beta}$*

For all the definitions and calculations concerning the gear pair, a flank line angle for an external gear is considered as positive when it is right handed with respect to a helix line with the nominal lead and it is considered negative when it is left handed with respect to a helix line with the nominal lead. In case of an internal gear, the signs are opposite. Thus in case of a spur gear mating, equal errors with opposite signs cancel each other out.

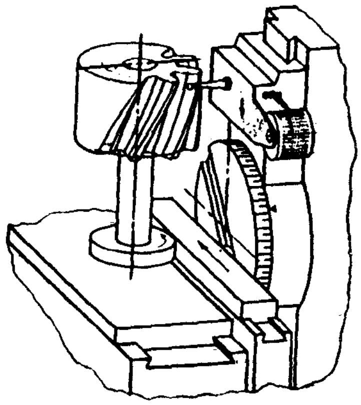


FIG. 8 APPARATUS FOR MEASURING TOOTH ALIGNMENT ERROR

Hence, there are two different definitions for the sign of the flank line angle error. In all production documents, test reports, etc, the direction of the effect of the errors should be clearly indicated.

In a test graph, as shown in Fig. 7, the flank line angle error, $f_{H\beta}$ is the distance measured perpendicular to the direction of the paper feed, between the lines *C'C'* and *C''C''* which are parallel to the line *AA* and cut the line *BB* at the end of the flank line test region.

6.3 Radial Run-Out Error, F_r

Radial run-out error, F_r of a gear is the radial positional difference of a measuring piece (Ball, cylinder or wedge), placed successively in all the tooth spaces, which touches the tooth flanks near the reference circle, while the gear is mounted on its guide axis, free to rotate. F_r is used to designate the maximum difference between the measurements at the gear periphery.

The simple method to measure the radial run-out error of small and medium diameter gears consists of successively introducing a ball or roller into all the tooth spaces, whilst the gear is supported between centres. The relative depths attained by the ball in the tooth spaces are read from a dial indicator. *See* Fig. 9.

6.4 Tooth Thickness Measurement

The measurement of tooth thickness is to guarantee the observance of a specified backlash for a given centre distance taking into account, the inevitable tooth errors:

a) Measurement independent of the axis is applied mainly for setting up the gear production machine. It should be noted that the specifying of the tooth thickness consistent with a likewise specified backlash at the theoretical centre distance postulates that all other errors are within their respective limits, particularly the radial and axial run-out. Thus the measurement of

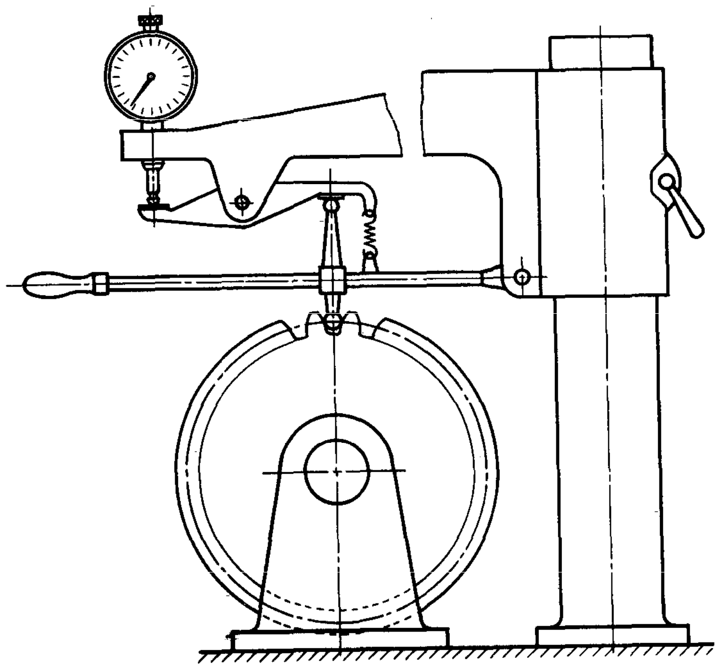


FIG. 9 MEASUREMENT OF RADIAL RUN-OUT ERROR

tooth thickness, independent of the axis can be regarded as a form of acceptance test only on condition that other errors (radial run-out in particular) are also inspected and remain within the limits specified.

b) The measurement of tooth thickness with reference to the axis, usually included in the acceptance test schedule, supplies the most important information for the determination of the effective tooth thickness, namely, the tooth thickness of an imaginary gear concentric with the axis, which encloses all the errors of the gear.

c) The theoretical tooth thickness measured on the reference cylinder is:

$$s = m\left[\frac{\pi}{2} \pm 2x.\tan\alpha\right]$$

The tooth thickness fluctuation, R_s is the difference between the maximum and minimum tooth thickness s of a gear:

$$R_s = s_{Max} - s_{Min}$$

6.4.1 *Measurement of the Tooth Thickness by Means of Gear Tooth Calipers*

a) *Measurement on the reference cylinder*

Refer Fig. 10. Measurement on the reference cylinder is given by:

$$\overline{s_n} = m.z_v.\sin\psi$$

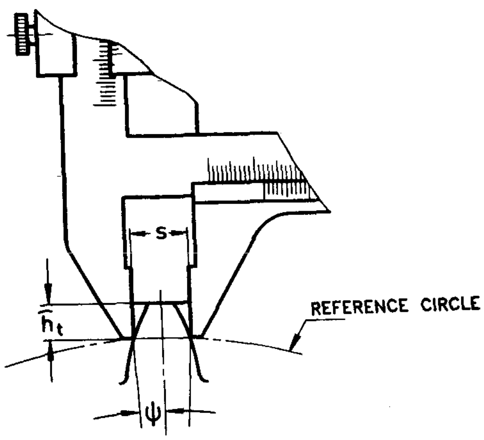


FIG. 10 MEASUREMENT OF TOOTH THICKNESS ON REFERENCE CYLINDER

$$\overline{h} = m + \frac{z_i}{2} m\,(1 - \cos\psi) \pm x.m$$

in which $\psi = \dfrac{\pi}{2z_v} \pm \dfrac{2x\,.\,\tan\alpha}{z_v}$ (in radians)

$\psi = \dfrac{90^\circ}{z_v}$ for gears without addendum modifications.

For spur gears: $z_v = z$

For helical gears : $z_v = z \dfrac{inv\,\alpha_t}{inv\,\alpha}$

For backlash allowance $\dfrac{j_n}{2}$, the dimension $\bar{s}$ is to be reduced by $\dfrac{j_n}{2\cos\alpha}$

For corrected gears the dimension $\bar{h}_a$ must be reduced by the appropriate amount.

b) *Inspection by constant chord method*

Refer Fig. 11, in this case, the measurement is not taken on the reference cylinder, but a little higher, which has a detrimental effect when the pressure angle is large and/ or the number of teeth is low.

$$\bar{s}_c = m \cdot \cos^2\alpha \left[\frac{\pi}{2} \pm 2x \cdot \tan\alpha\right]$$

$$\bar{h}_c = m\left[1 - \frac{\pi}{4}\sin\alpha\cos\alpha \pm x \cdot \cos^2\alpha\right]$$

For module = 1 and $\alpha = 20^\circ$, $\bar{s}_c = 1.387\ 05$ and $\bar{h}_c = 0.747\ 58$.

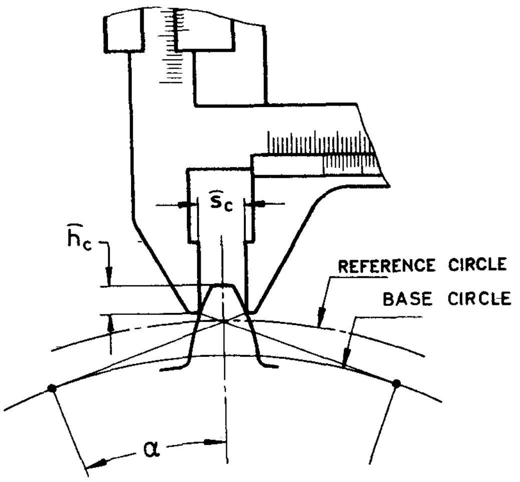


FIG. 11 INSPECTION OF TOOTH THICKNESS BY CONSTANT CHORD METHOD

6.4.2 *Tooth Width Measurement with the Aid of M-Test Dimension*

The tooth width M is the distance between two parallel planes each touching a right and left flank in the vicinity of the pitch circle, measured over k teeth. *See* Fig. 12. Its particular advantage is that it permits measurement of the tooth width independent of the outside diameter. Since the variations in the pitch also come into the measurement, it is necessary to measure at several points of the periphery. All individually measured tooth widths must lie within the tolerances in accordance with tooth thickness fluctuation, R_s.

Measurement is possible in case of both spur and helical gears. In case of helical gears, measurement has to be made in the normal plane.

NOTE — ± sign used in the formulae given in the text means plus sign for positive correction and minus sign for negative correction and the absolute value of x is to be substituted in the formulae.

6.4.2.1 *General formulae*

The general formula for nominal dimension M of tooth width is:

$$M = m_n \cos\alpha_n\,[(k - 0.5)\,\pi + z \cdot inv\,\alpha_t] + 2x.m_n.\sin\alpha_n. \quad .....(1)$$

To ensure the contact between the measuring jaws and tooth flanks is made near half the tooth depth, k must be calculated from:

$$k = \frac{z}{\pi}\left[\frac{\tan\alpha_{wt}}{\cos^2\beta_b} - 2.\frac{x}{z}\tan\alpha_n - inv\,\alpha_t\right] + 0.5 \quad .....(2)$$

k must always be rounded off to a whole number. The transverse working pressure angle α_{wt} on the cylinder with the diameter $(d + 2x.m_n)$ can be calculated from:

$$\cos\alpha_{wt} = \cos\alpha_t \frac{z}{z + 2x \cdot \cos\beta} \quad .....(3)$$

The helix angle on the base cylinder is computed from:

$$\tan\beta_b = \tan\beta\cos\alpha_t \quad .....(4)$$

The transverse pressure angle is calculated from:

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta} \quad .....(5)$$

6.4.2.2 *Gears without profile correction*

a) *Spur gears*

The tooth width 'M' in case of a spur gear is calculated from:

$$M = m\cos\alpha\,[(k - 0, 0.5)\,\pi + z.inv\,\alpha] \quad .....(6)$$

The number of teeth measured is computed from the formula:

$$k = z\frac{\alpha^\circ}{180^\circ} + 0, 0.5 \text{ (rounded off to whole number)} \quad ......(7)$$

In case of spur gears, without profile correction with module = 1; the value of k and the width M_1 for the pressure angles $\alpha = 14.5^\circ$, 15°, 20° and 30° can be obtained from the Tables 3 to 6. With any given module, the tooth width is computed from:

$$M = M_1.m. \quad ......(8)$$

Table 3 Tooth Width of Gears Without Profile Correction, Module = 1, Pressure Angle = 14.5°

(*Clause* 6.4.2.2)

z = number of teeth in gear blank, k = number of teeth measured, M_1 = tooth width for module 1

$p_e = m.\pi \cos 14.5° = 3.041\ 527.\ m$

$\alpha = 14.5°$

z	k	M1	z	k	M1	z	k	M1	z	k	M1	z	k	M1
			51	5	13.960 7	101	9	26.395 2	151	13	38.829 7	201	17	51.264 2
			52	5	13.966 0	102	9	26.400 6	152	13	38.835 1	202	17	51.269 6
			53	5	13.971 4	103	9	26.406 0	153	13	38.840 4	203	17	51.274 9
			54	5	13.976 8	104	9	26.411 3	154	13	38.845 8	204	17	51.280 3
			55	5	13.982 1	105	9	26.416 7	155	13	38.851 2	205	17	51.285 7
			56	5	13.987 5	106	9	26.422 0	156	13	38.856 5	206	17	51.291 1
			57	5	13.992 9	107	9	26.427 4	157	13	38.861 9	207	17	51.296 4
8	2	4.605 2	58	5	13.998 2	108	9	26.432 8	158	13	38.867 3	208	17	51.301 8
9	2	4.610 6	59	5	14.003 6	109	9	26.438 1	159	13	38.872 7	209	17	51.307 1
10	2	4.616 0	60	5	14.009 0	110	9	26.443 5	160	13	38.878 0	210	17	51.312 5
11	2	4.621 3	61	5	14.014 3	111	9	26.448 9	161	13	38.883 4	211	18	54.359 4
12	2	4.626 7	62	6	17.061 2	112	10	29.495 8	162	14	41.930 3	212	18	54.364 8
13	2	4.632 1	63	6	17.066 6	113	10	29.501 1	163	14	41.935 6	213	18	54.370 1
14	2	4.637 4	64	6	17.072 0	114	10	29.506 5	164	14	41.941 0	214	18	54.375 5
15	2	4.642 8	65	6	17.077 3	115	10	29.511 9	165	14	41.946 4	215	18	54.380 9
16	2	4.648 2	66	6	17.082 7	116	10	29.517 2	166	14	41.951 8	216	18	54.386 3
17	2	4.653 6	67	6	17.088 1	117	10	29.522 6	167	14	41.957 1	217	18	54.391 7
18	2	4.658 9	68	6	17.093 4	118	10	29.528 0	168	14	41.962 5	218	18	54.397 0
19	2	4.664 3	69	6	17.098 8	119	10	29.533 3	169	14	41.967 9	219	18	54.402 4
20	2	4.669 7	70	6	17.104 2	120	10	29.538 7	170	14	41.973 2	220	18	54.407 8
21	2	4.675 0	71	6	17.109 6	121	10	29.544 1	171	14	41.978 6	221	18	54.413 1
22	2	4.680 4	72	6	17.114 9	122	10	29.549 4	172	14	41.984 0	222	18	54.418 5
23	2	4.685 8	73	6	17.120 3	123	10	29.554 8	173	14	41.989 3	223	18	54.423 9
24	2	4.691 1	74	6	17.125 7	124	11	32.601 7	174	15	45.036 2	224	19	57.470 8
25	3	7.738 0	75	7	20.172 6	125	11	32.607 1	175	15	45.041 6	225	19	57.476 1
26	3	7.743 4	76	7	20.177 9	126	11	32.612 4	176	15	45.047 0	226	19	57.481 5
27	3	7.748 7	77	7	20.183 3	127	11	32.617 8	177	15	45.052 3	227	19	57.486 9
28	3	7.754 1	78	7	20.188 7	128	11	32.623 2	178	15	45.057 7	228	19	57.492 2
29	3	7.759 5	79	7	20.194 0	129	11	32.628 5	179	15	45.063 1	229	19	57.497 6
30	3	7.764 9	80	7	20.199 4	130	11	32.633 9	180	15	45.068 4	230	19	57.502 9
31	3	7.770 2	81	7	20.204 8	131	11	32.639 3	181	15	45.073 8	231	19	57.508 3
32	3	7.775 6	82	7	20.210 1	132	11	32.644 7	182	15	45.079 2	232	19	57.513 7
33	3	7.781 0	83	7	20.215 5	133	11	32.650 0	183	15	45.084 5	233	19	57.519 1
34	3	7.786 3	84	7	20.220 9	134	11	32.655 4	184	15	45.089 9	234	19	57.524 4
35	3	7.791 7	85	7	20.226 2	135	11	32.660 8	185	15	45.095 3	235	19	57.529 8
36	3	7.797 1	86	7	20.231 6	136	11	32.666 1	186	15	45.100 7	236	20	60.576 7
37	3	7.802 4	87	8	23.278 5	137	12	35.713 0	187	16	48.147 6	237	20	60.582 1
38	4	10.849 3	88	8	23.288 9	138	12	35.718 4	188	16	48.152 9	238	20	60.587 4
39	4	10.854 7	89	8	23.289 2	139	12	35.722 4	189	16	48.158 3	239	20	60.592 8
40	4	10.860 1	90	8	23.294 6	140	12	35.729 1	190	16	48.163 7	240	20	60.598 2
41	4	10.865 4	91	8	23.300 0	141	12	35.734 5	191	16	48.169 0	241	20	60.603 6
42	4	10.870 8	92	8	23.305 3	142	12	35.739 9	192	16	48.174 4	242	20	60.608 9
43	4	10.876 2	93	8	23.310 7	143	12	35.745 2	193	16	48.179 8	243	20	60.614 3
44	4	10.881 6	94	8	23.316 0	144	12	35.750 6	194	16	48.185 1	244	20	60.619 6
45	4	10.886 9	95	8	23.321 4	145	12	35.756 0	195	16	48.190 5	245	20	60.625 0
46	4	10.892 3	96	8	23.321 4	146	12	35.761 3	196	16	48.195 9	246	20	60.630 4
47	4	10.897 7	97	8	23.332 2	147	12	35.766 7	197	16	48.201 2	247	20	60.635 8
48	4	10.903 0	98	8	23.337 6	148	12	35.772 1	198	16	48.206 6	248	21	63.682 7
49	4	10.908 4	99	8	23.342 9	149	13	38.819 0	199	17	51.253 5	249	21	63.688 0
50	5	13.955 3	100	9	26.389 8	150	13	38.824 3	200	17	51.258 9	250	21	63.693 3

Table 4 Tooth Width of Gears Without Profile Correction, Module = 1, Pressure Angle = 15°

(*Clause* 6.4.2.2)

z = number of teeth in gear blank, k = number of teeth measured, M_1 = tooth width for module 1

$p_e = m.\pi \, . \cos 15° = 3.034\,546.m$

$\alpha = 15°$

z	k	M1	z	k	M1	z	k	M1	z	k	M1	z	k	M1
			51	5	13.958 4	101	9	26.393 6	151	13	38.828 8	201	17	51.264 0
			52	5	13.964 4	102	9	26.399 6	152	13	38.834 8	202	17	51.270 0
			53	5	13.970 3	103	9	26.405 5	153	13	38.840 7	203	17	51.275 9
			54	5	13.976 2	104	9	26.411 4	154	13	38.846 6	204	18	54.316 4
			55	5	13.982 2	105	9	26.417 4	155	13	38.852 6	205	18	54.322 3
			56	5	13.988 1	106	9	26.423 3	156	14	41.893 1	206	18	54.328 3
			57	5	13.994 1	107	9	26.429 3	157	14	41.899 0	207	18	54.334 2
8	2	4.599 3	58	5	14.000 0	108	10	29.469 8	158	14	41.905 0	208	18	54.340 2
9	2	4.605 3	59	5	14.005 9	109	10	29.475 7	159	14	41.910 9	209	18	54.346 1
10	2	4.611 2	60	6	17.046 4	110	10	29.481 6	160	14	41.916 8	210	18	54.352 0
11	2	4.617 2	61	6	17.052 4	111	10	29.487 6	161	14	41.922 8	211	18	54.358 0
12	2	4.623 1	62	6	17.058 3	112	10	29.493 5	162	14	41.928 7	212	18	54.363 9
13	2	4.629 0	63	6	17.064 3	113	10	29.499 5	163	14	41.934 7	213	18	54.369 9
14	2	4.635 0	64	6	17.070 2	114	10	29.505 4	164	14	41.940 6	214	18	54.375 8
15	2	4.640 9	65	6	17.076 1	115	10	29.511 3	165	14	41.946 5	215	18	54.381 8
16	2	4.646 9	66	6	17.082 1	116	10	29.517 3	166	14	41.952 5	216	19	57.422 2
17	2	4.652 8	67	6	17.088 0	117	10	29.523 2	167	14	41.958 4	217	19	57.428 2
18	2	4.658 7	68	6	17.094 0	118	10	29.529 1	168	15	44.998 9	218	19	57.434 1
19	2	4.664 7	69	6	17.099 9	119	10	29.535 1	169	15	44.004 9	219	19	57.440 1
20	2	4.670 6	70	6	17.105 8	120	11	32.575 6	170	15	44.010 8	220	19	57.446 0
21	2	4.676 6	71	6	17.111 8	121	11	32.581 5	171	15	44.016 7	221	19	57.451 9
22	2	4.682 5	72	7	20.152 3	122	11	32.587 5	172	15	44.022 7	222	19	57.457 9
23	2	4.688 4	73	7	20.158 2	123	11	32.593 4	173	15	44.028 6	223	19	57.463 8
24	3	7.728 9	74	7	20.164 1	124	11	32.599 3	174	15	44.034 6	224	19	57.469 8
25	3	7.734 9	75	7	20.170 1	125	11	32.605 3	175	15	44.040 5	225	19	57.475 7
26	3	7.740 8	76	7	20.176 0	126	11	32.611 2	176	15	44.046 4	226	19	57.481 6
27	3	7.746 7	77	7	20.182 0	127	11	32.617 2	177	15	44.052 4	227	19	57.487 6
28	3	7.752 7	78	7	20.187 9	128	11	32.623 1	178	15	44.058 4	228	20	60.528 0
29	3	7.758 6	79	7	20.193 8	129	11	32.629 1	179	15	44.064 3	229	20	60.534 0
30	3	7.764 6	80	7	20.199 8	130	11	32.635 0	180	16	48.104 7	230	20	60.539 9
31	3	7.777 0	81	7	20.205 7	131	11	32.640 9	181	16	48.110 7	231	20	60.545 9
32	3	7.776 4	82	7	20.211 7	132	12	35.681 4	182	16	48.116 6	232	20	60.551 8
33	3	7.782 4	83	7	20.217 6	133	12	35.687 4	183	16	48.122 6	233	20	60.557 8
34	3	7.788 3	84	8	23.258 1	134	12	35.693 3	184	16	48.128 5	234	20	60.563 7
35	3	7.794 3	85	8	23.264 0	135	12	35.699 2	185	16	48.134 4	235	20	60.569 7
36	4	10.834 8	86	8	23.270 0	136	12	35.705 2	186	16	48.140 4	236	20	60.575 6
37	4	10.840 7	87	8	23.275 9	137	12	35.711 1	187	16	48.146 3	237	20	60.581 5
38	4	10.846 6	88	8	23.281 9	138	12	35.717 1	188	16	48.152 3	238	20	60.587 5
39	4	10.852 6	89	8	23.287 8	139	12	35.723 0	189	16	48.158 2	239	20	60.593 4
40	4	10.858 5	90	8	23.293 7	140	12	35.728 9	190	16	48.164 1	240	21	63.633 9
41	4	10.864 4	91	8	23.299 7	141	12	35.734 9	191	16	48.170 1	241	21	63.639 8
42	4	10.870 4	92	8	23.305 6	142	12	35.740 8	192	17	51.210 6	242	21	63.645 8
43	4	10.876 4	93	8	23.311 6	143	12	35.746 8	193	17	51.216 5	243	21	63.651 7
44	4	10.882 3	94	8	23.317 6	144	13	38.787 2	194	17	51.222 5	244	21	63.657 7
45	4	10.888 2	95	8	23.323 4	145	13	38.793 2	195	17	51.228 4	245	21	63.663 6
46	4	10.894 2	96	9	26.363 9	146	13	38.799 1	196	17	51.234 3	246	21	63.669 5
47	4	10.900 1	97	9	26.369 9	147	13	38.805 1	197	17	51.240 3	247	21	63.675 5
48	5	13.940 6	98	9	26.375 8	148	13	38.811 0	198	17	51.246 2	248	21	63.681 4
49	5	13.946 5	99	9	26.381 7	149	13	38.817 0	199	17	51.252 2	249	21	63.687 4
50	5	13.952 5	100	9	26.387 7	150	13	38.822 9	200	17	51.258 1	250	21	63.003 3

Table 5 Tooth Width of Gears Without Profile Correction, Module = 1, Pressure Angle = 20°

(*Clause* 6.4.2.2)

z = number of teeth in gear blank, k = number of teeth measured, M_1 = tooth width for module 1

$p_e = m.\pi \cos 20° = 2.952\,133.m$

$\alpha = 20°$

z	k	M_1	z	k	M_1	z	k	M_1	z	k	M_1	z	k	M_1
			51	6	16.951 0	101	12	35.364 0	151	17	50.825 0	201	23	69.238 0
			52	6	16.965 0	102	12	35.378 1	152	17	50.839 0	202	23	69.252 0
			53	6	16.979 0	103	12	35.392 1	153	18	53.805 1	203	23	69.266 0
			54	7	19.945 1	104	12	35.406 1	154	18	53.819 1	204	23	69.280 0
			55	7	19.959 1	105	12	35.420 1	155	18	53.833 1	205	23	69.294 0
			56	7	19.973 2	106	12	35.434 1	156	18	53.847 1	206	23	69.308 1
			57	7	19.987 2	107	12	35.448 1	157	18	53.861 1	207	24	72.274 2
8	2	4.540 2	58	7	20.001 2	108	13	38.414 2	158	18	53.875 1	208	24	72.288 2
9	2	4.554 2	59	7	20.015 2	109	13	38.428 2	159	18	53.889 1	209	24	72.302 2
10	2	4.568 3	60	7	20.029 2	110	13	38.442 2	160	18	53.903 2	210	24	72.316 2
11	2	4.582 2	61	7	20.043 2	111	13	38.456 2	161	18	53.917 2	211	24	72.330 2
12	2	4.596 3	62	7	20.057 2	112	13	38.470 2	162	19	56.883 3	212	24	72.344 2
13	2	4.610 3	63	8	23.023 3	113	13	38.484 2	163	19	56.897 3	213	24	72.358 2
14	2	4.624 3	64	8	23.037 3	114	13	38.498 2	164	19	56.911 3	214	24	72.372 2
15	2	4.638 3	65	8	23.051 3	115	13	38.512 3	165	19	56.925 2	215	24	72.386 2
16	2	4.652 3	66	8	23.065 3	116	13	38.526 2	166	19	56.939 3	216	25	75.352 4
17	2	4.666 3	67	8	23.079 3	117	14	41.492 4	167	19	56.953 3	217	25	75.366 4
18	3	7.632 4	68	8	23.093 3	118	14	41.506 4	168	19	56.967 3	218	25	75.380 4
19	3	7.646 4	69	8	23.107 4	119	14	41.520 4	169	19	56.981 3	219	25	75.394 4
20	3	7.660 4	70	8	23.121 4	120	14	41.534 4	170	19	56.995 3	220	25	75.408 4
21	3	7.674 4	71	8	23.135 4	121	14	41.548 8	171	20	59.961 5	221	25	75.422 4
22	3	7.688 4	72	9	26.101 5	122	14	41.562 4	172	20	59.975 5	222	25	75.436 4
23	3	7.702 5	73	9	26.115 5	123	14	41.576 4	173	20	59.989 5	223	25	75.450 4
24	3	7.716 4	74	9	26.129 5	124	14	41.590 4	174	20	60.003 5	224	25	75.464 4
25	3	7.730 5	75	9	26.143 5	125	14	41.604 4	175	20	60.017 5	225	26	78.430 5
26	3	7.744 5	76	9	26.157 5	126	15	44.570 6	176	20	60.031 5	226	26	78.444 6
27	4	10.710 6	77	9	26.171 5	127	15	44.584 6	177	20	60.045 5	227	26	78.458 6
28	4	10.724 6	78	9	26.185 5	128	15	44.598 6	178	20	60.059 5	228	26	78.472 6
29	4	10.738 6	79	9	26.199 5	129	15	44.612 6	179	20	60.073 5	229	26	78.486 6
30	4	10.752 6	80	9	26.213 5	130	15	44.626 6	180	21	63.039 7	230	26	78.500 6
31	4	10.766 6	81	10	29.179 7	131	15	44.640 6	181	21	63.053 7	231	26	78.514 6
32	4	10.780 6	82	10	29.193 7	132	15	44.654 6	182	21	63.067 7	232	26	78.528 6
33	4	10.794 6	83	10	29.207 7	133	15	44.668 6	183	21	63.081 7	233	26	78.542 6
34	4	10.808 6	84	10	29.221 7	134	15	44.682 6	184	21	63.095 7	234	27	81.508 7
35	4	10.822 6	85	10	29.235 7	135	16	47.648 8	185	21	63.109 7	235	27	81.522 7
36	5	13.788 8	86	10	29.249 7	136	16	47.662 8	186	21	63.123 7	236	27	81.536 7
37	5	13.802 8	87	10	29.263 7	137	16	47.676 8	187	21	63.137 7	237	27	81.550 7
38	5	13.816 8	88	10	29.277 7	138	16	47.690 8	188	21	63.151 7	238	27	81.564 7
39	5	13.830 8	89	10	29.291 7	139	16	47.704 8	189	22	66.117 8	239	27	81.578 8
40	5	13.844 8	90	11	32.257 9	140	16	47.718 8	190	22	66.131 8	240	27	81.592 8
41	5	13.858 8	91	11	32.271 9	141	16	47.732 8	191	22	66.145 8	241	27	81.606 8
42	5	13.872 8	92	11	32.285 9	142	16	47.746 8	192	22	66.159 8	242	27	81.620 8
43	5	13.886 8	93	11	32.299 9	143	16	47.760 8	193	22	66.173 8	243	28	84.586 9
44	5	13.900 8	94	11	32.313 9	144	17	50.726 9	194	22	66.187 9	244	28	84.600 9
45	6	16.867 0	95	11	32.327 9	145	17	50.740 9	195	22	66.201 9	245	28	84.614 9
46	6	16.881 0	96	11	32.341 9	146	17	50.754 9	196	22	66.215 9	246	28	84.628 9
47	6	16.895 0	97	11	32.356 9	147	17	50.769 0	197	22	66.229 9	247	28	84.642 9
48	6	16.909 0	98	11	32.369 9	148	17	50.783 0	198	23	69.196 0	248	28	84.656 9
49	6	16.923 0	99	12	35.336 0	149	17	50.797 0	199	23	69.210 0	249	28	84.670 9
50	6	16.937 0	100	12	35.350 0	150	17	50.811 0	200	23	69.224 0	250	28	84.684 9

Table 6 Tooth Width of Gears Without Profile Correction, Module = 1, Pressure Angle = 30°

(*Clause* 6.4.2.2)

z = number of teeth in gear blank, k = number of teeth measured, M_1 = tooth width for module 1

$p_e = m.\pi \cos 30° = 2.720\ 698.m$

$\alpha = 30°$

z	k	M_1	z	k	M_1	z	k	M_1	z	k	M_1	z	k	M_1
			51	9	25.500 0	101	17	49.593 0	151	26	76.406 8	201	34	100.499 9
			52	9	25.546 5	102	18	52.360 3	152	26	76.453 3	202	34	100.546 4
			53	9	25.593 1	103	18	52.406 8	153	26	76.499 9	203	34	100.593 0
			54	10	28.360 3	104	18	52.453 4	154	26	76.546 4	204	38	103.360 2
5	2	4.313 8	55	10	28.406 9	105	18	52.499 9	155	26	76.593 0	205	35	103.406 8
6	2	4.360 3	56	10	28.453 4	106	18	52.546 5	156	27	79.360 2	206	35	103.453 3
7	2	4.406 9	57	10	28.500 0	107	18	52.593 0	157	27	79.406 8	207	35	103.499 9
8	2	4.453 4	58	10	28.546 5	108	19	55.360 3	158	27	79.453 3	208	35	103.546 4
9	2	4.500 0	59	10	28.593 1	109	19	55.406 8	159	27	79.499 9	209	35	103.593 0
10	2	4.546 5	60	11	31.360 3	110	19	55.453 4	160	27	79.546 4	210	36	106.360 3
11	2	4.593 1	61	11	31.406 9	111	19	55.499 9	161	27	79.593 0	211	36	106.406 8
12	3	7.360 3	62	11	31.453 4	112	19	55.464 8	162	28	82.360 2	212	36	106.453 3
13	3	7.406 9	63	11	31.500 0	113	19	55.593 0	163	28	82.406 8	213	36	106.499 9
14	3	7.453 4	64	11	31.546 5	114	20	58.360 3	164	28	82.453 3	214	36	106.546 4
15	3	7.500 0	65	11	31.593 1	115	20	58.406 8	165	28	82.499 9	215	36	106.590 0
16	3	7.546 5	66	12	34.360 3	116	20	58.453 4	166	28	82.546 4	216	37	109.360 2
17	3	7.593 1	67	12	34.406 9	117	20	58.499 9	167	28	82.593 0	217	37	109.406 7
18	4	10.360 3	68	12	34.453 4	118	20	58.546 5	168	29	85.360 2	218	37	109.453 3
19	4	10.406 9	69	12	34.500 0	119	20	58.593 0	169	29	85.406 8	219	37	109.499 8
20	4	10.453 4	70	12	34.546 5	120	21	61.360 3	170	29	85.453 3	220	37	109.546 4
21	4	10.500 0	71	12	34.593 1	121	21	61.406 8	171	29	85.499 9	221	37	109.593 0
22	4	10.546 5	72	13	37.360 3	122	21	61.453 4	172	29	85.546 4	222	38	112.360 2
23	4	10.593 1	73	13	37.406 9	123	21	61.499 9	173	29	85.593 0	223	38	112.406 7
24	5	13.360 3	74	13	37.453 4	124	21	61.546 7	174	30	88.360 2	224	38	112.453 3
25	5	13.406 8	75	13	37.500 0	125	21	61.593 0	175	30	88.406 8	225	38	112.499 8
26	5	13.453 4	76	13	37.546 5	126	22	64.360 3	176	30	88.453 3	226	38	112.546 4
27	5	13.499 9	77	13	37.593 0	127	22	64.406 8	177	30	88.499 9	227	38	112.592 9
28	5	13.546 5	78	14	40.360 3	128	22	64.453 4	178	30	88.546 4	228	39	115.360 2
29	5	13.593 1	79	14	40.406 8	129	22	64.499 9	179	30	88.593 0	229	39	115.406 7
30	6	16.360 3	80	14	40.453 4	130	22	64.546 5	180	31	91.360 2	230	39	115.453 3
31	6	16.406 9	81	14	40.499 0	131	22	64.593 0	181	31	91.406 8	231	39	11.499 8
32	6	16.453 4	82	14	40.546 5	132	23	67.360 3	182	31	91.453 3	232	39	115.546 4
33	6	16.500 0	83	14	40.593 0	133	23	67.406 8	183	31	91.499 9	233	39	115.592 9
34	6	16.546 5	84	15	43.360 4	134	23	67.453 4	184	31	91.546 4	234	40	118.360 2
35	6	16.593 1	85	15	43.406 9	135	23	67.499 9	185	31	91.593 0	235	40	118.406 7
36	7	19.360 3	86	15	43.453 4	136	23	67.546 5	186	32	94.360 2	236	40	118.453 3
37	7	19.406 9	87	15	43.500 0	137	23	67.593 0	187	32	94.406 8	237	40	118.499 8
38	7	19.453 4	88	15	43.546 6	138	24	70.360 3	188	32	94.453 3	238	40	118.546 4
39	7	19.500 0	89	15	43.593 1	139	24	70.406 8	189	32	94.499 9	239	40	118.592 9
40	7	19.546 5	90	16	46.360 3	140	24	70.453 3	190	32	94.546 4	240	41	121.360 2
41	7	19.593 1	91	16	46.406 8	141	24	70.499 9	191	32	94.593 0	241	41	121.406 7
42	8	22.360 3	92	16	46.458 4	142	24	70.546 5	192	33	97.360 2	242	41	121.453 3
43	8	22.406 9	93	16	46.499 9	143	24	70.593 0	193	33	97.406 8	243	41	121.499 8
44	8	22.453 4	94	16	46.546 5	144	25	73.360 3	194	33	97.453 3	244	41	121.546 4
45	8	22.500 0	95	16	46.593 0	145	25	73.406 8	195	33	97.499 9	245	41	121.592 9
46	8	22.546 5	96	17	49.360 3	146	25	73.453 5	196	33	97.546 4	246	42	124.360 2
47	8	22.593 1	97	17	49.406 8	147	25	73.499 9	197	33	97.593 0	247	42	124.406 7
48	9	25.360 3	98	17	49.453 4	148	25	73.546 5	198	34	100.360 2	248	42	124.453 3
49	9	25.406 9	99	17	49.499 9	149	25	73.593 0	199	34	100.406 8	249	42	124.499 8
50	9	25.453 4	100	17	49.546 5	150	26	76.360 2	200	34	100.453 3	250	42	124.546 4

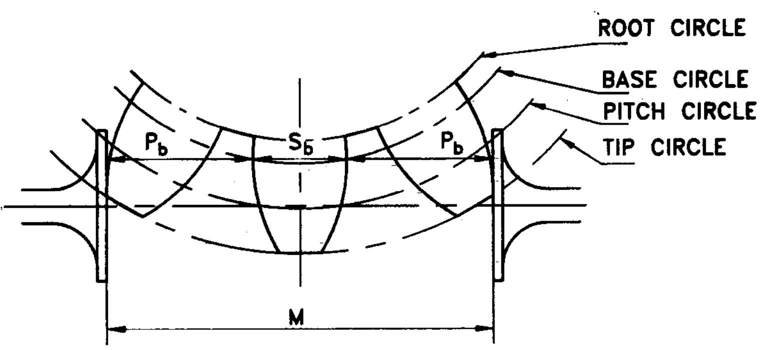


FIG. 12 MEASUREMENT OF TOOTH WIDTH

b) *Helical gears*

In case of helical gears the tooth width is computed from:

$M = m_n . \cos\alpha_n \, [(k - 0, 0.5)\, \pi + z . inv\, \alpha_t]$ .....(9)

and the number of teeth is measured from:

$$k = z \left[\frac{\alpha_t^o}{180^o} + \frac{\tan\alpha_t \tan^2 \beta_b}{\pi} \right] + 0.5 \quad ......(10)$$

for $\alpha_n = 20^o$, k can be obtained from Fig. 13.

By introducing, constants that can be tabulated, formula 4 can be simplified as follows:

$$M = m_n (A + z . C_1) \quad .....(11)$$

where $A = (k - 0.5)\pi . \cos\alpha_n$

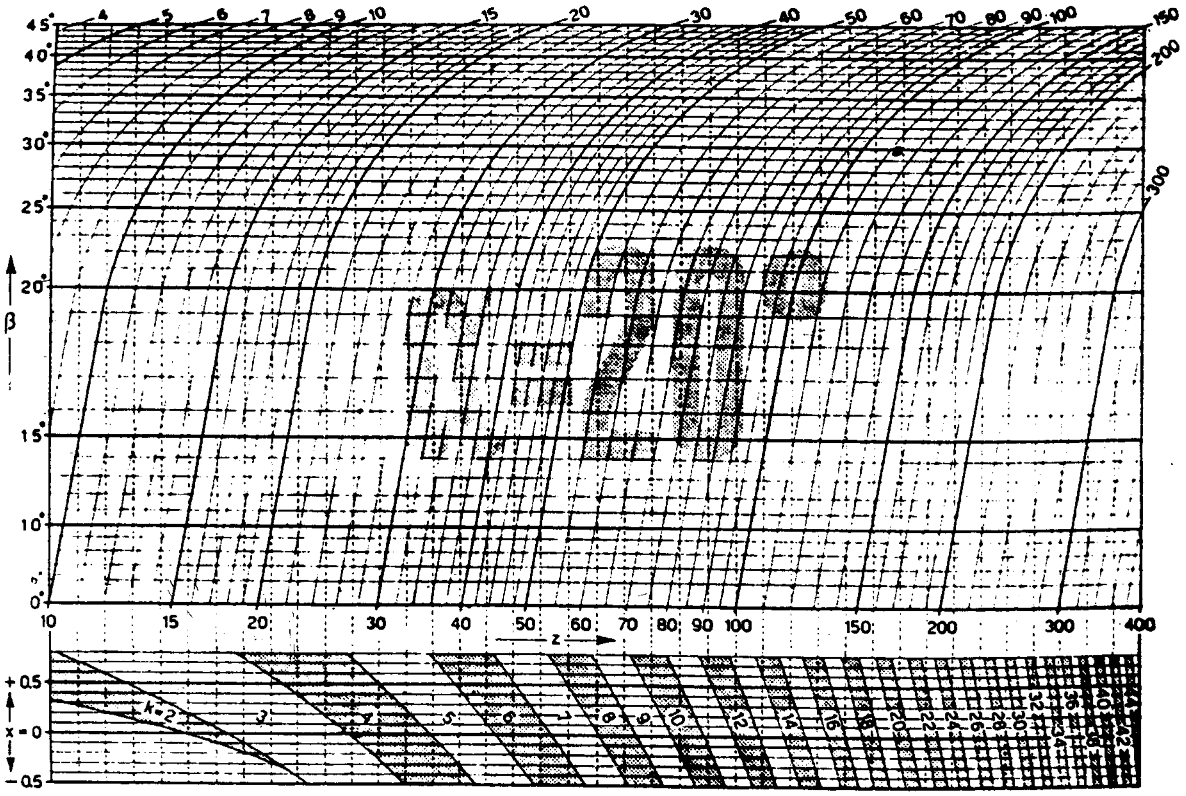
$C_1 = \text{inv } \alpha_t . \cos\alpha_n$

The values of A for various values of k are given in Table 7. The values of C_1 for various helix angles β and various pressure angles α_n can be obtained from Table 8. The minimum face width b required for M-measurement is calculated from formula 19.

6.4.2.3 *Gears with profile correction*

a) *Spur gears*

The nominal dimension M of the tooth width of a spur gear with profile correction factor x over k teeth is:



All dimensions in millimetres.

FIG. 13 NUMBER OF TEETH MEASUREMENT FOR $\alpha_n = 20^o$

Table 7 Factor *A*

(*Clause* 6.4.2.2)

k	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$	k	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$
				21	62.351 3	62.208 2	60.518 7
2	4.562 3	4.551 8	4.428 2	22	65.392 9	65.242 7	63.470 9
3	7.603 8	7.586 4	7.380 3	23	68.434 3	68.277 3	66.423 0
4	10.645 3	10.620 9	10.332 5	24	71.475 9	71.311 8	69.375 1
5	13.686 9	13.655 4	13.284 6	25	74.517 4	74.346 4	72.327 2
6	16.728 4	16.690 0	16.236 7	26	77.558 9	77.381 0	75.279 4
7	19.769 9	19.724 5	19.188 9	27	80.600 5	80.415 5	78.231 5
8	22.811 5	22.759 1	22.141 0	28	83.642 0	83.450 0	81.183 6
9	25.853 0	25.793 6	25.093 1	29	86.683 5	86.484 6	84.135 8
10	28.894 5	28.828 2	28.045 3	30	89.725 0	89.519 1	87.087 9
11	31.936 0	31.862 7	30.997 4	31	92.766 6	92.553 7	90.040 0
12	34.977 6	34.897 3	33.949 5	32	95.808 1	95.588 2	92.292 2
13	38.019 1	37.931 8	36.901 6	33	98.849 6	98.622 7	95.944 3
14	41.060 6	40.966 4	39.853 8	34	101.891 1	101.657 3	98.896 4
15	44.102 1	44.000 9	42.805 9	35	104.932 7	104.691 8	101.848 6
16	47.143 7	47.035 5	45.758 1	36	107.974 2	107.726 4	104.800 7
17	50.185 2	50.070 0	48.710 2	37	111.015 7	110.761 0	107.752 8
18	53.226 7	53.104 5	51.662 3	38	114.057 2	113.795 5	110.705 0
19	56.268 2	56.139 1	54.614 5	39	117.098 8	116.830 0	113.657 1
20	59.309 8	59.173 6	57.566 6	40	120.140 3	119.864 5	116.609 2

$$M = m\cos\alpha[(k-0,5)\,\pi + z.\mathrm{inv}\alpha] + 2xm\sin\alpha \qquad ....(12)$$

Number of teeth measured, k is computed from:

$$k = \frac{z}{\pi}\left[\tan\alpha_w - 2\frac{x}{z}\tan\alpha - \mathrm{inv}\alpha\right] + 0.5 \qquad .....(13)$$

By introducing constant C_2, the formula 12 can be simplified as:

$$M = m.(M_1 + C_2) \qquad .....(14)$$

Value of C_2 can be obtained from Table 9.

Value of M_1 can be obtained from Tables 3 to 6.

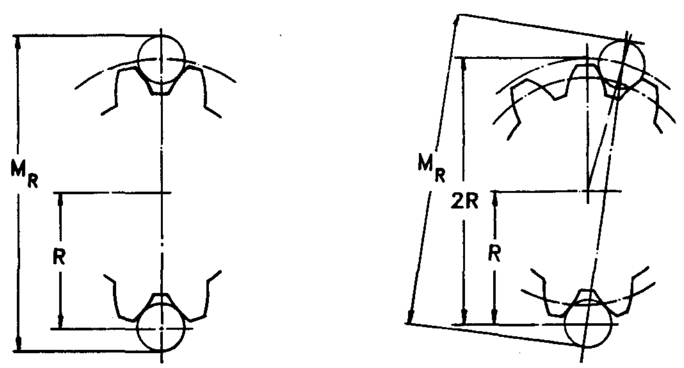
The effective pressure angle α_w on the diameter $(d + 2xm)$ is computed from:

$$\cos\alpha_w = \cos\alpha\,\frac{z}{z+2x} \qquad .....(15)$$

b) *Helical gears*

The nominal dimension M of the tooth width of a helical gear with profile correction over k teeth according to formula 1 is:

$$M = m_n\cos\alpha_n\,[(k-0,5)\,\pi + z.\mathrm{inv}\,\alpha_t] + 2xm_n\sin\alpha_n \qquad .....(16)$$



a) EVEN NUMBER OF TEETH b) ODD NUMBER OF TEETH

FIG. 14 DIMENSION OVER BALLS OR PINS FOR EXTERNAL GEARS

Table 8 Factor C_1
(*Clause* 6.4.2.2)

β	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$
0°	0.0053 68	0.005 940	0.014 005
1°	0.005 370	0.005 943	0.014 011
2°	0.005 378	0.005 950	0.014 030
3°	0.005 390	0.005 967	0.014 061
4°	0.005 407	0.005 982	0.014 103
5°	0.005 428	0.006 007	0.014 159
6°	0.005 455	0.006 036	0.014 227
7°	0.005 486	0.006 071	0.014 307
7° 10' 51"	0.005 493	0.006 078	0.014 325
8°	0.005 522	0.006 112	0.014 402
9°	0.005 564	0.006 155	0.014 510
10°	0.005 614	0.006 212	0.014 632
10°48'25"	0.005 657	0.006 259	0.014 740
11°	0.005 673	0.006 271	0.014 767
12°	0.005 727	0.006 336	0.014 917
13°	0.005 791	0.006 408	0.015 083
14°	0.005 863	0.006 504	0.015 262
14°28'40"	0.005 899	0.006 527	0.015 355
15°	0.005 940	0.006 572	0.015 461
16°	0.006 025	0.006 666	0.015 675
17°	0.006 115	0.006 765	0.015 908
18°	0.006 215	0.006 875	0.016 159
18°12'36"	0.006 238	0.006 900	0.016 213
19°	0.006 323	0.006 994	0.016 430
20°	0.006 437	0.007 121	0.016 721
21°	0.006 561	0.007 256	0.017 033
22°	0.006 694	0.007 403	0.017 369

β	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$
22° 01'28"	0.006 697	0.007 407	0.017 377
23°	0.006 836	0.007 561	0.017 728
24°	0.006 988	0.007 723	0.018 113
25°	0.007 153	0.007 914	0.018 526
25°56'40"	0.007 317	0.008 092	0.018 942
26°	0.007 327	0.008 102	0.018 968
27°	0.007 515	0.008 310	0.019 440
28°	0.007 716	0.008 531	0.019 944
29°	0.007 931	0.008 770	0.020 484
30°	0.008 161	0.009 024	0.021 062
31°	0.008 409	0.009 296	0.021 680
32°	0.008 674	0.009 588	0.022 341
33°	0.008 957	0.009 900	0.023 049
34°	0.009 254	0.010 237	0.023 808
35°	0.009 588	0.010 598	0.024 621
36°	0.009 932	0.010 983	0.025 492
37°	0.010 316	0.011 399	0.026 427
38°	0.010 721	0.011 849	0.027 431
39°	0.011 160	0.012 330	0.028 510
40°	0.011 632	0.012 849	0.029 672
41°	0.012 243	0.013 410	0.030 921
42°	0.012 690	0.014 014	0.032 269
43°	0.013 287	0.014 670	0.033 723
44°	0.013 931	0.015 358	0.035 295
45°	0.014 632	0.016 149	0.036 994

k the number of teeth measured, computed from formula 2 is:

$$k = \frac{Z}{\pi}\left[\frac{\tan\alpha_{wt}}{\cos^2\beta_b} - 2\frac{x}{z}\tan\alpha_n - inv\ \alpha_t\right] + 0.5 \qquad .....(17)$$

k, for $\alpha_n = 20°$ can be obtained from Fig. 13.

The transverse working pressure angle α_{wt} on the diameter $(d + 2xm_n)$ follows from:

$$\cos\alpha_{wt} = \cos\alpha_t \frac{z}{z + 2x\cos\beta} \qquad .....(18)$$

By using factors A, C_1, C_2 the following formula is obtained:

$$M = m_n\,(A + z \,.\, C_1 + C_2) \qquad .....(19)$$

where

$A = (k - 0.5)\pi \cos\alpha_n$ according to Table 7,

$C_1 = \cos\alpha_n . inv\alpha_t$ according to Table 8, and

$C_2 = 2x \sin\alpha_n$ according to Table 9.

Table 9 Factor C_2

(*Clause* 6.4.2.3)

x[1)]	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$	x[1)]	$\alpha_n = 14.5°$	$\alpha_n = 15°$	$\alpha_n = 20°$
0.01	0.005 0	0.005 2	0.006 8	0.51	0.255 4	0.2640	0.3489
0.02	0.010 0	0.010 4	0.013 7	0.52	0.260 4	0.2692	0.3557
0.03	0.015 0	0.015 5	0.020 5	0.53	0.265 4	0.2743	0.3625
0.04	0.020 0	0.020 7	0.027 4	0.54	0.270 4	0.2795	0.3694
0.05	0.025 0	0.025 9	0.034 2	0.55	0.275 4	0.2847	0.3762
0.06	0.030 0	0.031 1	0.041 0	0.56	0.280 4	0.2899	0.3831
0.07	0.035 0	0.036 2	0.047 9	0.57	0.285 4	0.2951	0.3899
0.08	0.040 0	0.041 4	0.054 7	0.58	0.290 4	0.3002	0.3967
0.09	0.045 1	0.046 6	0.061 6	0.59	0.295 4	0.3054	0.4036
0.10	0.050 1	0.051 8	0.068 4	0.60	0.300 5	0.3106	0.4104
0.11	0.055 1	0.056 9	0.075 2	0.61	0.305 5	0.3158	0.4173
0.12	0.060 1	0.062 1	0.082 1	0.62	0.310 5	0.3209	0.4241
0.13	0.065 1	0.067 3	0.088 9	0.63	0.315 5	0.3261	0.4309
0.14	0.070 1	0.072 5	0.095 8	0.64	0.320 5	0.3313	0.4378
0.15	0.075 1	0.077 6	0.102 6	0.65	0.325 5	0.3365	0.4446
0.16	0.080 1	0.082 8	0.109 4	0.66	0.330 5	0.3416	0.4515
0.17	0.085 1	0.088 0	0.116 3	0.67	0.335 5	0.3468	0.4583
0.18	0.090 1	0.093 2	0.123 1	0.68	0.340 5	0.3520	0.4651
0.19	0.095 1	0.098 4	0.130 0	0.69	0.345 5	0.3572	0.4720
0.20	0.100 2	0.103 5	0.136 8	0.70	0.350 5	0.3623	0.4788
0.21	0.105 2	0.108 7	0.143 6	0.71	0.355 5	0.3675	0.4857
0.22	0.110 2	0.113 9	0.150 5	0.72	0.360 5	0.3727	0.4925
0.23	0.115 2	0.119 1	0.157 3	0.73	0.365 6	0.3779	0.4993
0.24	0.120 1	0.124 2	0.164 2	0.74	0.370 6	0.3831	0.5062
0.25	0.125 2	0.129 4	0.171 0	0.75	0.375 6	0.3882	0.5130
0.26	0.130 2	0.134 6	0.177 9	0.76	0.380 6	0.3934	0.5199
0.27	0.135 2	0.139 8	0.184 7	0.77	0.385 6	0.3986	0.5267
0.28	0.140 2	0.144 9	0.191 5	0.78	0.390 6	0.4038	0.5336
0.29	0.145 2	0.150 1	0.198 4	0.79	0.395 6	0.4089	0.5404
0.30	0.150 2	0.155 3	0.205 2	0.80	0.400 6	0.4141	0.5472
0.31	0.155 2	0.160 5	0.212 1	0.81	0.405 6	0.4193	0.5541
0.32	0.160 2	0.165 6	0.218 9	0.82	0.410 6	0.4245	0.5609
0.33	0.165 2	0.170 8	0.225 7	0.83	0.415 6	0.4296	0.5678
0.34	0.170 3	0.176 0	0.232 6	0.84	0.420 6	0.4348	0.5746
0.35	0.175 3	0.181 2	0.239 4	0.85	0.425 6	0.4400	0.5814
0.36	0.180 3	0.186 4	0.246 3	0.86	0.430 7	0.4452	0.5883
0.37	0.185 3	0.191 5	0.253 1	0.87	0.435 7	0.4503	0.5951
0.38	0.190 3	0.196 7	0.259 9	0.88	0.440 7	0.4555	0.6020
0.39	0.195 3	0.201 9	0.266 8	0.89	0.445 7	0.4607	0.6088
0.40	0.200 3	0.207 1	0.273 6	0.90	0.450 7	0.4659	0.6156
0.41	0.205 3	0.212 2	0.280 5	0.91	0.455 7	0.4711	0.6225
0.42	0.210 3	0.217 4	0.287 3	0.92	0.460 7	0.4762	0.6293
0.43	0.215 3	0.222 6	0.294 1	0.93	0.465 7	0.4814	0.6362
0.44	0.220 3	0.227 8	0.301 0	0.94	0.470 7	0.4866	0.6430
0.45	0.225 3	0.232 9	0.307 8	0.95	0.475 7	0.4918	0.6498
0.46	0.230 3	0.238 1	0.314 7	0.96	0.480 7	0.4969	0.6567
0.47	0.235 4	0.243 3	0.321 5	0.97	0.485 7	0.5021	0.6635
0.48	0.240 4	0.248 5	0.328 3	0.98	0.490 7	0.5073	0.6704
0.49	0.245 4	0.253 6	0.335 2	0.99	0.495 7	0.5125	0.6772
0.50	0.250 4	0.258 8	0.342 0	1.00	0.500 7	0.5176	0.6840

1) In the case of negative profile correction a minus sign (–) must be placed before the values C_2.

To ensure that two parallel planes touch the flanks, the face width must be:

$$b \geq M \sin\beta_b + b_M \cos\beta_b \quad .....(20)$$

$$\tan\beta_b = \tan\beta \cdot \cos\alpha_t$$

where b_M = Constant line overlap or width of the measuring surface in tooth width measurement.

For gears without chamfering

$$b_M > 1.2 + 0.018M$$

$$b_M > 2.0 + 0.03M$$

Summary of the important formulae for the tooth width measurement with the aid of M-test dimension for spur and helical gears are furnished in Table 10.

6.4.3 *Tolerance on M-Test Dimension*

The upper allowance and tolerance on M-test dimension can be obtained by multiplying the upper tooth thickness allowance (A_{sne}) and tooth thickness tolerance (T_{sn}) values from Tables 7 and 8 of IS 3681 : 1995, respectively by $\cos\alpha_n$.

6.4.4 *Tooth Thickness Measurement Over Pins or Balls*

Tooth thickness can be determined by taking the measurement over pins or balls placed in diametrically opposite tooth spaces as shown in Fig. 14 and Fig. 15. This method is suitable for both external and internal spur and helical gears. The size of the balls or pins should be selected in such a way that they touch the tooth flanks on or approximately near the reference circle.

The theoretical dimension, M_R over the pins or balls can be calculated from Table 11. The selection of pin or ball diameter and the calculation procedure for other parameters are given in Table 12.

The tolerance on dimension, M_R over pins or balls can be obtained by multiplying the upper tooth thickness allowance (A_{sne}) and tooth thickness tolerance. (T_{sn}) values from Tables 7 and 8 of IS 3681 : 1995, respectively by a factor given by $\dfrac{\cos\alpha_t}{\sin\alpha_{Rt} \cdot \cos\beta}$.

6.5 Blue Bearing Test (TRA)

Due to various gear errors and influence of working conditions, a gear flank will not have full bearing on the mating flank in a gear mesh. The blue bearing test indicates the bearing zone of one flank with its mating flank.

7 INSPECTION OF GEAR TEETH IN ASSEMBLY CONDITIONS

7.1 Single Flank Total Composite Error Testing

In this test two gears are meshed and rotated at the prescribed centre distance with either the right or left flanks in constant contact. *See* Fig. 16. The single flank composite errors of the right flank are generally different from those of left flank of the same gear. The deviations of the rotating positions of the gear with respect to nominal positions given by the positions of the mating gear and by the ratio of the number of teeth are measured starting from a start position. For this, a comparative measuring device is required where the error free rotating angle positions are obtained. The errors are generally indicated as paths along with circumference of a measuring circle, for example, the reference circle or base circle. The errors can also be given in angles.

7.1.1 *Single Flank Total Composite Error, F_i'*

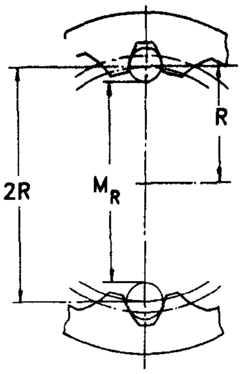
In a circular test graph as shown in Fig. 17, the single flank total composite error, F_i' is the difference between the maximum and minimum distance of the recorded test graph from the axis of rotation of the test chart, namely, F_i' is the difference between the maximum and minimum Y-axis of the test graph.

7.1.2 *Single Flank Tooth to Tooth Composite Error, f_i'*

The single flank tooth to tooth composite error, f_i' is the maximum difference that occurs in the rotating positions deviations within a rotating angle corresponding to the period of a tooth contact.

7.2 Double Flank Total Composite Error Testing

In this test two gears are meshed with each other and rotated with a left and right flank of the gears always in contact at the same time (two flank contact) under the influence of a force acting in the direction of the centre distance. *See* Fig. 18. In this process, the changes of the centre distance are measured. The centre distance found in the double flank composite error testing is designated as a''.



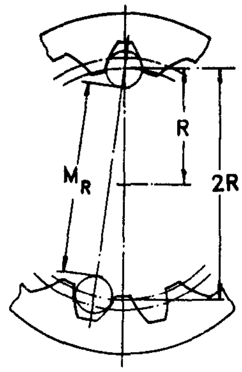


FIG. 15 DIMENSION OVER BALLS OR PINS FOR INTERNAL GEARS

Table 10 Summary of Important Formulae for the Tooth Width Measurement
(*Clause* 6.4.2.3)

Gear Profile		Tooth Width, M	Number of Teeth Measured, k
Gears without profile correction	Spur gears	$M = m \cdot M_1$	According to Tables 3 to 6
	Helical gears	$M = m_n (A + z \cdot C_1)$	According to Fig. 13
Gears with profile correction	Spur gears	$M = m \cdot (M_1 + C_2)$	According to Tables 3 to 6 or Fig. 13[1)]
	Helical gears	$M = m_n (A + z \cdot C_1 + C_2)$	According to Fig. 13

M_1 = according to Tables 3 to 6
A = according to Table 7
C_1 = according to Table 8
C_2 = according to Table 9

[1)] Check whether the value of k read from Tables 3 to 6 and also from Fig. 13 are the same. If the value is not same, use the formulae 12 and 13 of **6.4.2.3** to evaluate M and k.

7.2.1 *Double Flank Total Composite Error, F_i''*

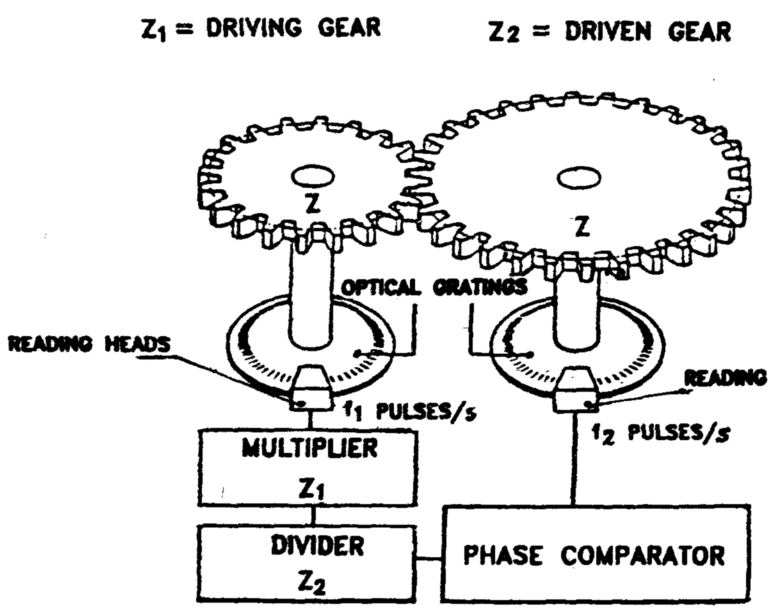
Refer Fig. 19. The double flank total composite error, F_i'' is the difference between the maximum and minimum working centre distance within one test rotation.

7.2.2 *Radial Run-Out Error, F_r*

The radial run-out error, F_r is the longwave component of the test diagram. This component can be obtained by drawing an averaging line thereby suppressing the short-wave components. The radial run-out error, F_r is the distance between the highest and lowest points of an averaging line.

7.2.3 *Double Flank Tooth to Tooth Composite Error, f_i''*

The double flank tooth to tooth composite error, f_i'' is the difference between the maximum and minimum working centre distance that occurs within a turning angle corresponding to the period of a tooth contact.



$$\frac{Z_1}{Z_2} = f_1 (= f_2) \text{ PULSES/s}$$

FIG. 16 BLOCK DIAGRAM OF CIRCUIT FOR SINGLE FLANK TESTING

Table 11 Calculation of Theoretical Dimension Over Pins or Balis, M_R

(*Clause* 6.4.4)

Dimension		External Gears		Internal Gears	
		Spur Gears	Helical Gears	Spur Gears	Helical Gears
Dimension over pins or balls	With even No. of teeth	$M_R = m.z\frac{\cos\alpha}{\cos\alpha_R} + D_M$	$M_R = m_t.z\frac{\cos\alpha_t}{\cos\alpha_{rt}} + D_M$	$M_R = m.z\frac{\cos\alpha}{\cos\alpha_R} - D_M$	$M_R = m_t.z\frac{\cos\alpha_t}{\cos\alpha_{Rt}} - D_M$
	With odd No. of teeth	$M_R = m.z\frac{\cos\alpha.\cos\left(\frac{90^\circ}{z}\right)}{\cos\alpha_R} + D_M$	$M_R = m_t.z\frac{\cos\alpha_t.\cos\left(\frac{90^\circ}{z}\right)}{\cos\alpha_{Rt}} + D_M$	$M_R = m.z\frac{\cos\alpha.\cos\left(\frac{90^\circ}{z}\right)}{\cos\alpha_R} - D_M$	$M_R = m_t.z\frac{\cos\alpha_t.\cos\left(\frac{90^\circ}{z}\right)}{\cos\alpha_{Rt}} - D_M$

Table 12 Calculation of d_R, α_R, α_{Rt} and ψ

(*Clause* 6.4.4)

Gears		External Gears	Internal Gears
Pin or ball touching the tooth flanks above the reference circle (without correction)	Spur gears	$D_M \approx 1.728m$ $\text{Inv}\,\alpha_R = \text{inv}\alpha + \frac{\alpha_R}{mz\cos\alpha} - \frac{\pi}{2z} \pm \frac{2x\tan\alpha}{z}$ 1)	$D_M \approx 1.44m$ 1) $\text{inv}\alpha_R = \text{inv}\alpha - \frac{\alpha_R}{mz\cos\alpha} + \frac{\pi}{2z} \pm \frac{2x\tan\alpha}{z}$ 1)
	Helical gears	$D_M \approx 1.728m_n$ $\text{Inv}\,\alpha_{Rt} = \text{inv}\alpha_t + \frac{d_R}{mn\,z\cos\alpha_n} - \frac{\pi}{2z} \pm \frac{2x\tan\alpha_n}{z}$ 1)	$D_M \approx 1.44m_n$ $\text{inv}\alpha_{Rt} = \text{inv}\alpha_t + \frac{d_R}{m_n z\cos\alpha_n} - \frac{\pi}{2z} \pm \frac{2x\tan\alpha_n}{z}$ 1)
Pin or ball touching the tooth flanks on the reference circle	Spur gears	$D_M \approx m.z\sin\psi/\cos\alpha_R$ $\psi = \frac{\pi}{2z} - \left(\pm\frac{2x\tan\alpha}{z}\right)$ 1) $\alpha_R = \alpha - \psi$	$D_M = mz\sin\psi/\cos\alpha_R$ $\psi = \frac{\pi}{2z} - \left(\pm\frac{2x\tan\alpha}{z}\right)$ 1) $\alpha_R + \alpha - \psi$
	Helical gears	$D_M = \frac{m_n z\sin\psi\cos\alpha_n}{\cos\alpha_{Rt}\cdot\cos\alpha_t}$ $\psi = \frac{\pi}{2z} - \left(\pm\frac{2x\tan\alpha_n}{z}\right)$ 1) $\alpha_{Rt} = \alpha_t + \psi$	$D_M = \frac{m_n z\sin\psi\cos\alpha_n}{\cos\alpha_{Rt}\cdot\cos\alpha_t}$ $\psi = \frac{\pi}{2z} - \left(\pm\frac{2x\tan\alpha_n}{z}\right)$ 1) $\alpha_{Rt} = \alpha_t - \psi$
Pin or ball touching the tooth flanks below the reference circle	Spur gears	$D_M = \frac{\pi}{z} m\cdot\cos\alpha$ $\text{inv}\,\alpha_R = \text{inv}\alpha \pm \frac{2x\tan\alpha}{z}$ 1)	
	Helical gears	$D_M = \frac{\pi}{2} m_n\cdot\cos\alpha_n$ $\text{inv}\alpha_{Rt} = \text{inv}\alpha_t \pm \frac{2x\tan\alpha_n}{z}$ 1)	

1) Use + sign for positive correction and – sign for negative correction. Substitute the absolute value of x in the equations.

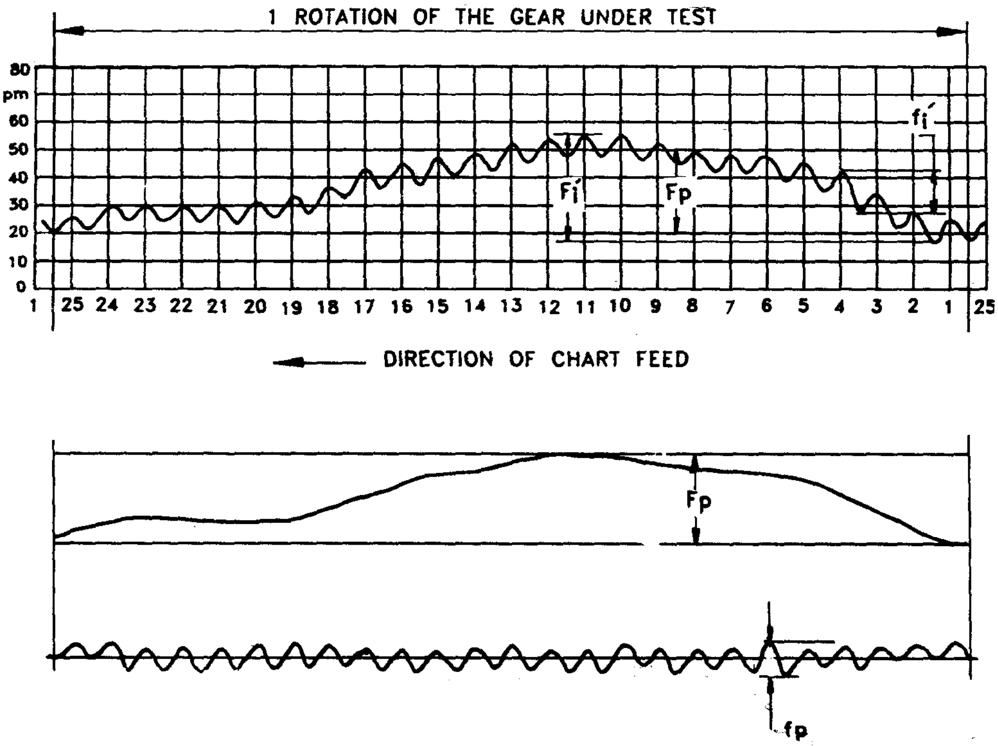


FIG. 17 SINGLE FLANK TOTAL COMPOSITE ERROR DIAGRAM

8 INSPECTION OF INVOLUTE RACKS

8.1 Corresponding to the measurement of external gears, the racks are checked for following values:

- Tooth thickness,
- Penetrating depth of a pin or ball (corresponding to runout of a gear),
- Double flank composite error, and
- Profile.

For the inspection of tooth thickness, the measurement with balls or pins is the most accurate procedure. Refer Fig. 20.

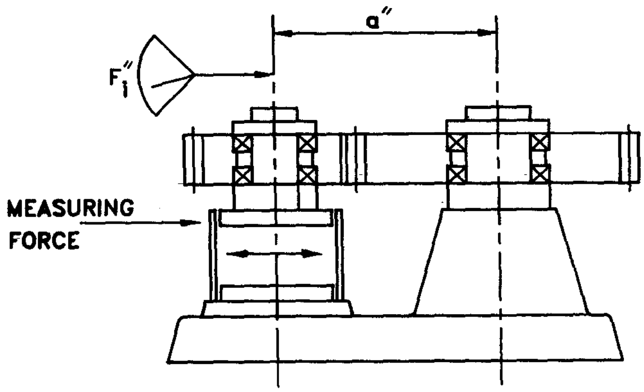


FIG. 18 TESTING ON DOUBLE FLANK TOTAL COMPOSITE ERROR

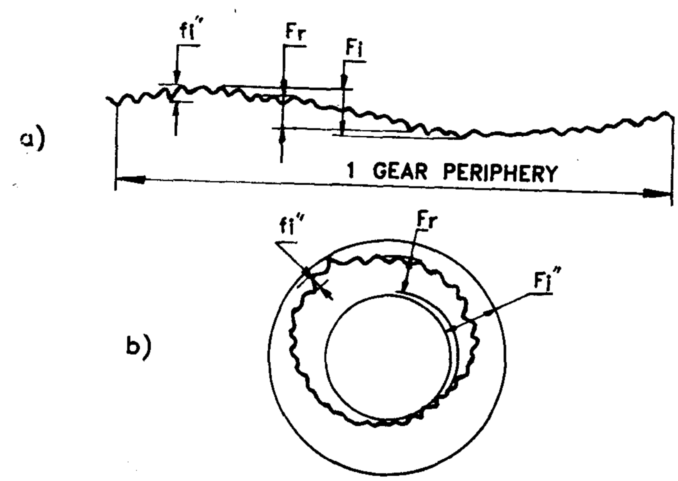


FIG. 19 DOUBLE FLANK TOTAL COMPOSITE ERROR DIAGRAM

The dimension M_R, over pins or balls is given by the formula:

$$M_R = b + \frac{D_M}{2}\left(\frac{1}{\sin\alpha_n} + 1\right) - \frac{m_n\pi}{4\tan\alpha_n}$$

The pin or ball diameter, D_M can be calculated from

$$D_M = \frac{m_n\pi}{2\cos\alpha_n}$$ (Round off to a standard pin or ball diameter)

For double flank composite error testing of racks of limited length, double flank checking machines with suitable attachments are employed.

Measuring microscopes and profile projectors are suitable for profile and pitch inspection of racks.

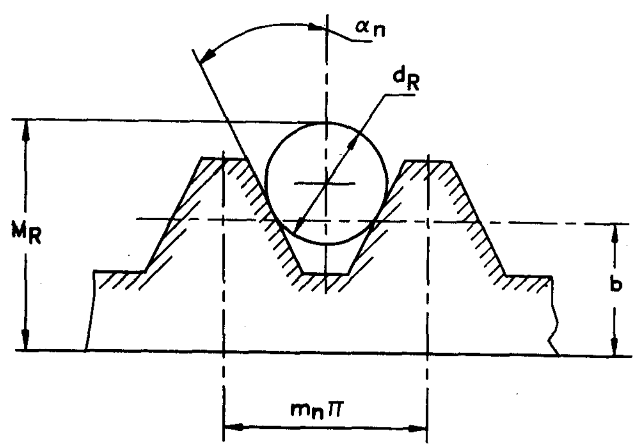


FIG. 20 INSPECTION OF TOOTH THICKNESS

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